

Influence of Crop Residues and Organic Manures on the Hydrolysis of Urea in a Typic Haplustept

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The emphasis on integrated use of organic amendments and fertilizers has made it imperative to study the effect of crop residues and organic manures on urea hydrolysis, which governs the release of N from urea fertilizer. Urea hydrolysis in soils is an enzymatic decomposition process facilitated by the extracellular enzyme urease. Our aim was to assess the influence of crop residues (rice straw, wheat straw) and organic manures (poultry manure, farm yard manure, cowpea, and sesbania) on urea hydrolysis by conducting a laboratory incubation experiment employing a Hasanpur silt loam soil (coarse loamy, mixed, hypothermic Typic Haplustept). The study was conducted at a constant temperature of $33 \pm 1^\circ\text{C}$ at two moisture levels (1:1 soil:water ratio and field capacity). The results showed that the rate of urea hydrolysis decreased with an increase in time of incubation (12 to 96 h), while the disappearance of urea N was associated with the corresponding increase in $(\text{NH}_4^+ + \text{NO}_3^-)\text{-N}$ content in soils treated with crop residues and organic manures. In the nonamended soil, the time required for the complete hydrolysis of the applied urea ($200 \mu\text{g urea N g}^{-1}$ soil) was more than 96 h at both the moisture levels, whereas in amended soils, 60 to 72 h of incubation periods were required for urea hydrolysis. The rate of urea hydrolysis in the amended soil was of the following order: sesbania > cowpea > poultry manure > farmyard manure > rice straw and wheat straw, irrespective of the moisture regime. Urea hydrolysis followed first-order kinetics in all the treatments at both moisture levels. The rate constant value for urease activity was higher at field capacity, indicating that urea hydrolysis proceeded rapidly under the condition of field capacity rather than saturated conditions (1:1 soil:water ratio).

Keywords crop residues, moisture regimes, organic manures, urea hydrolysis

The future sustainability of crop production will greatly depend upon the improvement in the effective management of soils. The use and management of crop residues, farmyard manure, and green manure are an increasingly important aspect of environmentally sound sustainable agriculture (Timsina and Connor, 2001). Application of green manures and crop residues help in increasing the organic matter content of soil, improve soil-water relationships, and enhance the N availability in soil (Singh et al., 1992).

In India, more than 80% of nitrogen is applied as urea. When urea is applied to moist soil, it is hydrolyzed to ammonium carbonate through the action of the

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extracellular enzyme urease. Urea hydrolysis in soils is influenced by many factors including soil organic matter, clay, and water content (Kumar and Wagenet, 1984; Yadav et al., 1987), occurs rapidly in soil treated with crop residues, increases with higher amounts of organic amendments and longer periods of incubation (Khind et al., 1991; Saini et al., 1994). The enzymatic transformation of urea into ammonium carbonate proceeds quickly but losses of urea N through leaching may be significant. Leaching experiments in soil columns have demonstrated that urea moves through soil with irrigation water depending on the rate of water application (Antil et al., 1992). It has been found that the rate of urea hydrolysis was slow in saturated soils as compared to field capacity (Wali et al., 2003) and occurred at a higher rate at 40% versus 60% water-holding capacity (Sankhayan and Shukla, 1976). Information on the influence of crop residue additions and organic manures on urea hydrolysis in relation to applied water is limited. Therefore, a laboratory incubation study was conducted to investigate the effect of crop residues and organic manures on urea hydrolysis and its kinetics in a *Typic Haplustept* of Punjab (India) at two moisture regimes.

Materials and Methods

The soil used in this study was Hasanpur silt loam (coarse loamy, mixed, hypothermic *Typic Haplustept*) collected from farmers' fields in the Ludhiana district (75°41' E and 30°50' N) Punjab, India following the wheat harvest during the winter season of 2002–2003. Random subsamples (8 to 10) of moist soil were taken from 0–0.15 m depth and combined to make a bulk sample of approximately 50 kg. This bulk soil sample was thoroughly mixed to ensure uniformity, air-dried, ground to pass through 2 mm sieve and stored in polythene bags under field capacity condition (20% w/w) at room temperature (19–23°C) until the incubation was initiated to minimize disturbance of the soil. The experimental soil had pH (1:2 soil:water ratio) of 8.0 and an electrical conductivity (in the supernatant liquid of 1:2 soil:water solution stirred well and kept overnight) of 0.56 dSm⁻¹. Texture of the soil was silt loam as determined by the International Pipette Method (Day, 1965). The soil contained 0.17% organic carbon (Nelson and Sommers, 1996). The contents of alkaline KMnO₄ oxidizable N (Subbiah and Asija, 1956), 0.5 M NaHCO₃ (pH 8.5) extractable P (Watanabe and Olsen, 1965), and 1 N NH₄OAc (pH 7.0) extractable K (Pratt, 1982) were 53.1, 4.8, and 150.4 mg kg⁻¹, respectively. The initial concentration of mineral N (NH₄⁺ + NO₃⁻)-N was 28.0 mg kg⁻¹. The field capacity of the experimental soil was determined with a pressure plate apparatus at 0.33 bar, following the standard procedure described by Jalota et al., (1998). The crop residues viz. rice straw (RS) and wheat straw (WS) and organic manures viz. poultry manure (PM), farm-yard manure (FYM), cowpea (CP), and sesbania (S) were selected to study the effect of these organic materials on urea hydrolysis in the soil at two moisture regimes.

Treatment and Laboratory Analysis

From bulk soil samples, 5 g samples of soil were oven-dried and added to a series of polyethylene containers. The crop residues and organic manures were finely ground in a Wiley mill and sieved through a 0.5-mm sieve so that the residues and manures can mix well with the soil. The finely grinded crop residues and organic manures were mixed at 2% by weight with soil and 1 ml of distilled water was added to each

container to bring the soil to field capacity. These soil samples were incubated for 15 at a temperature of $33 \pm 1^\circ\text{C}$ for the decomposition (partial) of crop residues and organic manures. Following the 15-day incubation period, the study was conducted at two moisture levels (field capacity and 1:1 soil:water ratio). Urea was applied on the surface of soil in solution form as 1 ml and 5 ml at $200\text{-}\mu\text{g}$ urea N g^{-1} soil at field capacity and 1:1 soil:water ratio, respectively. After treating the soil samples with urea, the polyethylene containers were then incubated at $33 \pm 1^\circ\text{C}$ for 12, 24, 36, 48, 60, 72, and 96 h. The experiment was run in duplicate. The soil samples (5 gm) were immediately extracted (1:10 soil:extractant ratio) with 2M KCl containing $5\text{-}\mu\text{g ml}^{-1}$ of phenyl mercuric acetate (PMA). These extracts were analyzed for urea N by the diacetylmonoxime method (Mulvaney and Bremner, 1979) and $(\text{NH}_4^+ + \text{NO}_3^-)\text{-N}$ by distillation method using magnesium oxide and devarda's alloy (Bremner and Keeney, 1966). Urease activity in different treatments was determined by the nonbuffer method given by Zantua and Bremner (1975).

Modeling of Urea Hydrolysis

The data on urea hydrolysis was processed according to zero- and first-order kinetic models. These two equations are given below:

$$\begin{aligned}C_t &= C_0 + K_t \text{ (zero order)} \\ \ln C_t &= \ln C_0 - K_t \text{ (first order)}\end{aligned}$$

where K , rate constant (hr^{-1}); C_0 , initial concentration of added urea N (μg); C_t , concentration of urea N in soil solution at time "t"; t , time interval (h).

Results and Discussion

As expected, application of crop residues and organic manures significantly increased the rate of urea hydrolysis in the amended soils. Urea hydrolysis did not occur in all the amended soils at the start of the experiment (zero hours). In the control soil (urea only), the urea hydrolysis was not completed during the 96-h incubation period, whereas hydrolysis increased with increasing period of incubation (12 to 96 h) at both the moisture levels (1:1 soil:water ratio and field capacity) in all of the amended soils (Figures 1 and 2). The rate of urea hydrolysis was rapid up to 12 h of incubation followed by a slow increase in hydrolysis for all of the amended soils (Figure 2). The enhanced rate of urea hydrolysis due to the addition of crop residues and organic manures may be attributed to the stimulation of microbial activity and subsequent synthesis of urease. Frankenberger et al., (1983) and Reddy and Chhonkar (1991) also reported that urease activity in soil significantly increased with the addition of organic matter and was related to the C:N ratio of the applied organic materials. Urea hydrolysis was faster at field capacity than at 1:1 soil:water ratio treatment as higher levels of mineral $(\text{NH}_4^+ + \text{NO}_3^-)\text{-N}$ were determined under the conditions of field capacity (Figure 1). The decrease in urea N concentration also reflects a higher rate of urease enzyme activity at field capacity than at a 1:1 soil:water ratio. The slow rate of urea hydrolysis under saturated conditions could be due to the limited supply of oxygen which decreases the activity of urease. These results are consistent with the findings of Singh and Singh (1996). The influence of organic manure on urea hydrolysis was of the following

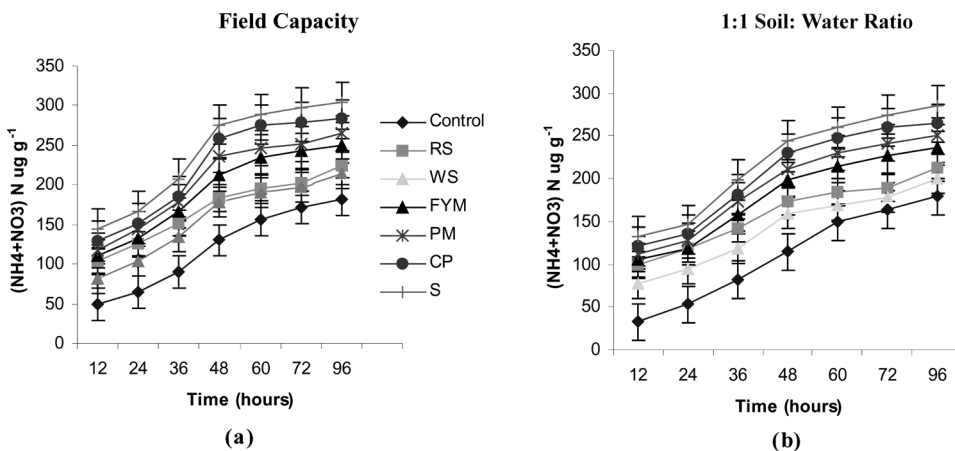


Figure 1. KCl-extractable $(\text{NH}_4 + \text{NO}_3)\text{-N}$ at different periods of incubation in Hasanpur silt loam soil at field capacity and 1:1 soil: water ratio. The vertical bars indicate standard errors. RS = rice straw, WS = wheat straw, FYM = farmyard manure, PM = poultry manure, CP = cowpea, and S = Sesbania.

order: sesbania > cowpea > poultry manure > farmyard manure > rice straw and wheat straw after each incubation period of 12, 24, 36, 48, 60, 72, and 96 h, irrespective of moisture level. This may be due to the fact that sesbania had the lowest C:N ratio (19:1), and the highest urease activity ($72.3\text{-}\mu\text{g}$ urea N hydrolyzed g^{-1} soil hr^{-1}) as compared to other organic manures and crop residues (Table 1). Therefore, soils amended with organic manures such as sesbania hydrolyzed significantly higher quantities of urea at a higher rate than the remaining crop residue treatments. In the sesbania-treated soil, 81.5% urea was hydrolyzed at field capacity (Figure 2a) as compared with 54% in wheat straw-treated soil after 24 h of

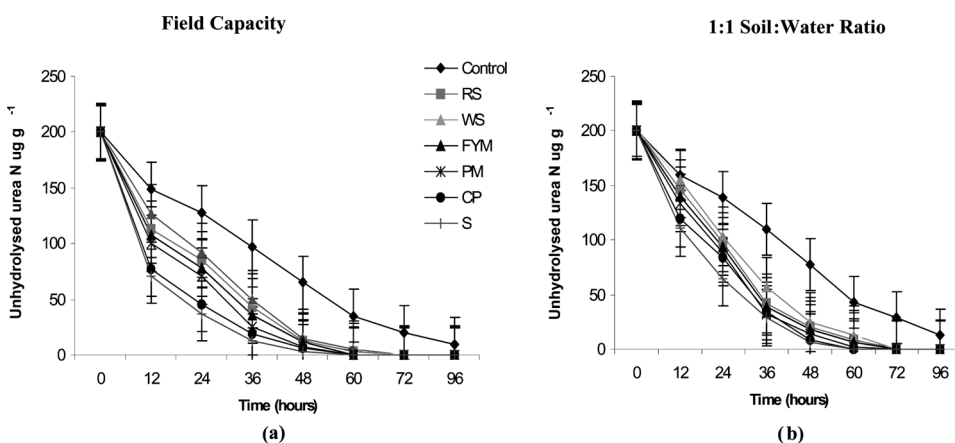


Figure 2. Unhydrolyzed urea N at different periods of incubation in Hasanpur silt loam soil at field capacity and 1:1 soil: water ratio. The vertical bars indicate standard errors. RS = rice straw, WS = wheat straw, FYM = farmyard manure, PM = poultry manure, CP = cowpea, and S = Sesbania.

Table 1. Urease activity, C:N ratio and nitrogen content of different crop residues and organic manures (duplicate analysis)

Treatments	Urease activity (μg urea N hydrolyzed g^{-1} soil hr^{-1})	Nitrogen $\text{g}/100 \text{ g}$ (w/w)	C:N ratio
Control	51.3	—	—
Rice straw	58.5	1.08	42:1
Wheat straw	54.9	0.96	48:1
Farmyard manure	62.1	1.16	28:1
Poultry manure	65.6	1.76	25:1
Cowpea	69.0	2.60	21:1
Sesbania	72.3	2.90	19:1
LSD ($p = 0.05$)	3.11	0.04	—

LSD = least square deviation: significant at $p = (0.05)$.

incubation, while the respective values of 67.5 and 48.5% at the 1:1 soil:water ratio was determined (Figure 2b). Furthermore, the C:N ratio of the organic amendments was significantly negatively correlated with urease activity ($r = -0.959^*$; Table 4). It is quite obvious that organic amendments having a higher C:N ratio would decompose at a slower rate, thereby lowering the availability of N. Singh and Bajwa (1986) also reported a negative correlation between urease activity and C:N ratio. Therefore, the minimum urease activity in wheat straw was probably due to its wider C:N ratio.

The decrease in urea N was paralleled by a concomitant increase in the mineral N ($\text{NH}_4^+ + \text{NO}_3^-$) concentration in the amended as well as nonamended soil during the incubation period (12 to 96 h). In the treated soils, the concentration of mineral ($\text{NH}_4^+ + \text{NO}_3^-$)-N was 125, 104, 132, 144, 151, and $167 \mu\text{g g}^{-1}$ soil at field capacity (Figure 1a), whereas it was 118, 95, 119, 128, 135, and $146 \mu\text{g g}^{-1}$ soil with 1:1 soil:water ratio (Figure 1b) after 24 h of incubation in RS, WS, FYM, PM, CP, and S-treated soils, respectively. These concentrations increased by 60 to 70% after 48 h of incubation at both the moisture levels. Dey and Jain (1997) also reported that the concentration of mineral N in amended soils was dependent on the C:N of organic manures. Consequently, mineral N was significantly higher in the sesbania-amended soil at both the moisture regimes. A peak concentration of mineral ($\text{NH}_4^+ + \text{NO}_3^-$)-N occurred after 48 h of incubation at field capacity, whereas 72 h of incubation was required at the 1:1 soil:water ratio (Figures 1a and 1b). These results may be due to a higher degree of urea hydrolysis at field capacity. Similar results were reported by Savant et al., (1985), Singh and Singh (1996), and Wali et al., (2003) in which the rate of urea hydrolysis was determined to be higher at field capacity as compared to saturated conditions because regulated oxygen diffusion under field capacity conditions maximizes the urease activity in the soil.

Kinetics of Urea Hydrolysis

The data on urea hydrolysis were modeled according to first and zero-order equations. The results in Table 2 showed that the first-order equation was found to be

Table 2. Coefficient of determination (R^2) of kinetic models in Hasanpur silt loam (duplicate analysis)

Treatments	Zero order (R^2)		First order (R^2)	
	1:1 Soil water	Field capacity	1:1 Soil water	Field capacity
Control	0.84	0.82	0.93	0.95
Rice straw	0.83	0.83	0.94	0.97
Wheat straw	0.86	0.84	0.92	0.97
Farmyard manure	0.82	0.89	0.96	0.93
Poultry manure	0.80	0.86	0.98	0.96
Cowpea	0.87	0.85	0.95	0.97
Sesbania	0.86	0.82	0.96	0.98

best in describing the urea hydrolysis with the addition of organic manures and crop residues as determined by the higher coefficient of determination (R^2) value. The plot of $\ln(C_t - C_0)$, the logarithm of the concentration of unhydrolyzed urea against time “t,” resulted in a linear relationship for all treatments at both the moisture regimes indicating that urea hydrolysis followed a first-order reaction. Overrein and Moe (1967), Singh (1990), and Kumar and Wagenet (1984) also reported that urea hydrolysis followed a first-order reaction. The rate constant (C_k) value in the nonamended soil was 0.058 hr^{-1} at 1:1 soil:water ratio and 0.063 hr^{-1} at field capacity (Table 3). In the amended soils, the rate constant values ranged from 0.090 to 0.108 hr^{-1} at 1:1 soil:water ratio and 0.096 to 0.115 hr^{-1} at field capacity. The average urea hydrolysis time at one half ($t^{1/2}$) was higher at field capacity than at the 1:1 soil:water ratio (Table 3). The higher rate constant and lower $t^{1/2}$ values in the amended soils may be attributed to greater urease activity associated with crop residues and organic manures because organic amendments in soil stimulate the microbial activity with subsequent synthesis of urease. Similar positive effects of organic manures on the rate of urea hydrolysis due to increased urease activity were also reported by Kumar and Wagenet (1984) and Singh et al.,

Table 3. First-order equation rate constant and $t^{1/2}$ values (duplicate analysis)

Treatments	Hasanpur silt loam			
	1:1 Soil water		Field capacity	
	K	$t^{1/2}$	K	$t^{1/2}$
Control	0.058	10.9	0.063	10.1
Rice straw	0.091	7.55	0.096	7.15
Wheat straw	0.090	7.57	0.095	7.27
Farmyard manure	0.093	7.50	0.102	6.87
Poultry manure	0.096	7.18	0.108	6.79
Cowpea	0.104	6.73	0.113	6.21
Sesbania	0.108	6.64	0.115	6.07

Table 4. Correlation between urease activity, C:N ratio and rate constants (duplicate analysis)

	Urease activity	C:N ratio
C:N ratio	-0.959*	—
Rate constant at field capacity	0.985*	-0.847*
Rate constant at 1:1 soil water ratio	0.952*	-0.951*

*Significant at $p = (0.05)$.

(1997). The highest rate constant and lowest $t^{1/2}$ values were found in the sesbania-treated soil due to the lowest C:N ratio and the greatest amount of urease activity for all the amended soils. Furthermore, the rate constant values were higher at field capacity than 1:1 soil:water ratio which may again be attributed to increased urease activity at field capacity. Although the urease activity was positively correlated with the determined rate constant values at both the moisture levels (Table 4), the relatively higher correlation value at field capacity ($r = 0.985^*$) confirms that there were higher amounts of mineral N at this moisture level than at a 1:1 soil water ratio. Vlek and Carter (1983), Yadav et al., (1987), and Panda (2005) also confirmed that hydrolysis rates of urea was more at field capacity soil moisture because oxygen becomes a limiting factor for the activity of urease enzyme under saturated conditions.

The results of the present study indicated that urea hydrolysis in all the treatments was higher at field capacity than at the 1:1 soil:water ratio due to higher urease activity associated with higher oxygen availability. Soils amended with organic manures hydrolyzed significantly higher quantities of urea at a faster rate than crop residues at field capacity. The rapid changes of urease activity, particularly at the soil surface can greatly alter urea hydrolysis, which may cause losses of N via ammonia volatilization and leaching with irrigation water. Therefore, there is need to assess the decomposition process of added organic residues and manures on controlling the losses of N. Urea hydrolysis followed first-order reaction kinetics in all the treatments at both moisture regimes. Thus, the rate constants describe the urea hydrolysis and may be used in a recommendation of N fertilizer for the crops.

References

- Antil, R. S., M. S. Gangwar, and V. Kumar. 1992. Transformation and movement of urea in soil as influenced by water application rate, moisture management regime and initial moisture content. *Arid Soil Research and Rehabilitation* 6:319–325.
- Bremner, J. M. and D. R. Keeney. 1966. Determination and isotope ratio analysis of different forms of nitrogen in the soils. 3 Exchangeable ammonium, nitrate and nitrite by extraction-distillation method. *Soil Science Society of American Proceedings* 30: 577–582.
- Day, P. R. 1965. Particle fractionation and particle size analysis, pp. 595–624, in A. L. Page, ed., *Methods of soil analysis*. American Society of Agronomy, Madison, WI.
- Dey, P. and J. M. Jain. 1997. Mineralization and nitrification in soil amended with urea and enriched green manures in submerged soil system. *Journal of the Indian Society of Soil Science* 45:249–255.

- Frankenberger, W. J., Jr J. B. Johnson, and C. O. Nelson. 1983. Urease activity in sewage sludge amended soils. *Soil Biology Biochemistry* 15:543–549.
- Jalota, S. K., R. Khera, and B. S. Ghuman. 1998. *Methods in soil physics*. Narosa Publishing House, New Delhi, India.
- Khind, C. S., A. Garg, and M. S. Bajwa. 1991. Effect of sesbania, rice straw and preincubation on urea hydrolysis in wet land soil. *International Rice Research Newsletter* 16:18.
- Kumar, V. and R. J. Wagenet. 1984. Urease activity and kinetics of urea transformation in soil. *Soil Science* 137:263–269.
- Mulvaney, R. L. and J. M. Bremner. 1979. A modified diacetylmonoxime method for colorimetric determination of urea and soil extracts. *Communication in Soil Science and Plant Analysis* 10:1163–1170.
- Nelson, D. W. and L. E. Sommers. 1996. Total carbon, organic carbon and organic matter, pp. 961–1010, in D. L. Sparkes et al. eds., *Methods of soil analysis. Part 3*. SSSA Book Series No. 5. American Society of Agronomy and Soil Science Society of America, Madison, WI.
- Overrein, L. N. and P. G. Moe. 1967. Factors affecting urea hydrolysis and ammonia volatilization in soil. *Soil Science Society of American Proceedings* 31:57–61.
- Panda, D. 2005. Chemistry of nitrogen transformation in submerged soils and scientific management of urea fertilizer for higher rice productivity. *Journal of the Indian Society of Soil Science* 53:500–513.
- Pratt, P. F. 1982. Potassium, pp. 225–246, in A. L. Page, R. H. Miller, and D. R. Keeney, eds., *Methods of soil analysis. Part II*. American Society of Agronomy, Madison, WI.
- Reddy, S. M. and P. K. Chhonkar. 1991. Urease activity in soils and flood water as influenced by regulatory chemicals and oxygen stress. *Journal of the Indian Society of Soil Science* 39:84–88.
- Saini, P., M. S. Bajwa, and C. S. Khind. 1994. Effect of decomposition period of added organic matter on urease activity and urea hydrolysis in flooded alkaline soil. *Journal of the Indian Society of Soil Science* 42:471–473.
- Sankhayan, S. D. and U. C. Shukla. 1976. Rates of urea hydrolysis in five soils of India. *Geoderma* 16:171–178.
- Savant, N. K., A. F. James, and G. M. McClellan. 1985. Effect of soil submergence on urea hydrolysis. *Soil Science* 140:81–88.
- Singh, B. 1990. Kinetics of urea hydrolysis and nitrification in some soils of Punjab. M.Sc. thesis, Punjab Agricultural University, Ludhiana, India.
- Singh, B. and M. S. Bajwa. 1986. Studies on urea hydrolysis in salt affected soils. *Fertilizer Research* 8:231–240.
- Singh, B. and L. Singh. 1996. Studies on urea hydrolysis in Typic Ustochrepts of Punjab. *Journal of the Indian Society of Soil Science* 44:638–643.
- Singh, J. P., V. Kumar, and D. S. Dabas. 1997. Effect of soil type, substrate concentration and organic amendments on urea hydrolysis. *Annals of Biology* 13:1–5.
- Singh, Y., B. Singh, and C. S. Khind. 1992. Nutrient transformations in soils amended with green manures. *Advances in Soil Science* 20:238–298.
- Subbiah, B. V. and G. L. Asija. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* 25:259–260.
- Timsina, J. and D. J. Connor. 2001. Productivity and management of rice-wheat systems. Issues and Challenges. *Field Crops Research* 69:93–132.
- Vlek, P. L. G. and M. F. Carter. 1983. The effect of soil environment and fertilizer modification on the rate of urea hydrolysis. *Soil Science* 136:56–63.
- Wali, P., V. Kumar, and J. P. Singh. 2003. Effect of soil type, exchangeable sodium percentage, water content and organic amendments on urea hydrolysis in some tropical Indian soils. *Australian Journal of Soil Research* 41:1171–1176.

- Watanabe, F. S. and S. R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorous in water and NaHCO_3 extracts. *Soil Science Society of American Proceedings* 29:677–678.
- Yadav, D. S., V. Kumar, M. Singh, and P. S. Relon. 1987. Effect of temperature and moisture on kinetics of urea hydrolysis and nitrification. *Journal of the Indian Society of Soil Science* 25:185–191.
- Zantua, M. I. and J. M. Bremner. 1975. Preservation of soil samples for assay of urease activity. *Soil Biology Biochemistry* 7:297–299.

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